High-Performance Global Climate Modeling

University of California
Lawrence Livermore National Laboratory

Mission

The Center for Applied Scientific Computing (CASC) and the LLNL Atmospheric Science Division (ASD) are working together to improve predictions of future climate by applying the best available computer resources to this problem. Over the last decade, researchers at Lawrence Livermore National Laboratory (LLNL) have developed a number of climate models that provide state-of-the-art simulations on a wide variety of massively parallel computers. We are now developing a second generation of high-performance climate models.

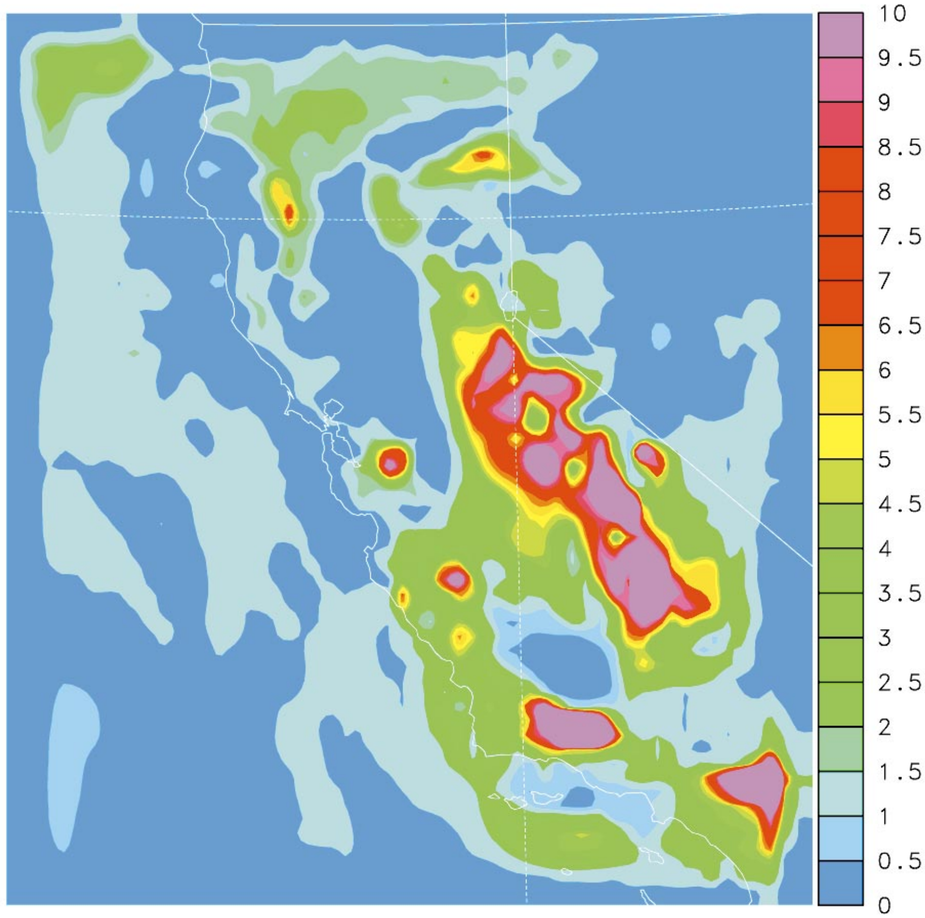

Figure 1. Precipitation in the western United States, as predicted by COAMPS mesoscale model.

Current CASC/ASD Projects

Global Climate Model Development

Members of CASC and ASD are developing a comprehensive, next-generation climate model. This model will incorporate the most current physics and numerics, and will capably exploit the latest massively parallel computers. Researchers are developing this model in collaboration with Los Alamos National Laboratory (LANL), the National Center for Atmospheric Research (NCAR), and other investigators.

Mesoscale Model Parallelization

In collaboration with the Naval Research Laboratory Monterey, CASC and ASD are "parallelizing" the Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) model, a regional meteorological and climate model. The Navy will implement the parallel version of COAMPS as an operational forecast model. Additionally, it will be used at LLNL for regional climate prediction and for use in calculations of the transport and fate of hazardous materials in the atmosphere.

Atmosphere/Sea Ice Model Parallelization

In collaboration with the University of Victoria (Victoria, BC, Canada) we have created a massively parallel version of the University's atmosphere/sea ice model. The atmospheric component of this code is a vertically integrated energy/moisture balance model. We will use this code in conjunction with a parallel ocean general circulation model to perform studies of natural climate variability on time scales of many decades to centuries.

Specific ASD Research Areas

ASD is involved in the following areas of climate research:

- Application of high-performance computing to climate simulation.
- Climate model diagnosis and intercomparison.
- Detection of anthropogenic climate change.
- Climate forcing by anthropogenic aerosols.
- Climate/chemistry interactions.
- Modeling the ocean circulation.
- The ocean carbon cycle.
- Simulating climates of the distant past.

Collaborators and Sponsors

Our collaborators in climate research include the LANL Advanced Computing Laboratory; the NCAR Climate and Global Dynamics Division; the University of Victoria, School of Earth and Ocean Sciences;

the Naval Research Laboratory Monterey; and the LLNL Center for Accelerator Mass Spectrometry.

Climate research at LLNL is funded by the U.S. Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA).

Recent Results

Regional Climate Simulation

We employed the Navy's COAMPS regional atmospheric model to simulate the effects of last winter's El Niño on the western United States. Figure 1 displays a simulation of precipitation in this region during the week of February 8–15, 1998.

Atmospheric Model Parallelization

LLNL has created a high-performance atmospheric climate model based on the UCLA atmospheric general circulation model. Figure 2 shows execution speed of the LLNL model as a function of the number of processors used in the calculation. Different curves show the performances on different machines. The horizontal line near the bottom of the plot shows the speed of the model on one processor of a Cray C90 vector supercomputer. The fastest multiprocessor machines can exceed the speed of the C90 by a factor of almost 50.

CFC Uptake

Recent simulations at LLNL demonstrated our improved ability to simulate chlorofluorocarbon (CFC) uptake by the ocean. This is important because ocean uptake of CFCs is closely related to ocean uptake of fossil-fuel carbon; thus, improved representation of CFC uptake presumably allows better prediction of ocean uptake of greenhouse gas carbon. Predicting ocean uptake of fossil-fuel carbon is important because the more fossil-fuel carbon becomes absorbed by the oceans, the less it remains in the atmosphere, and global warming will slow proportionally. Figure 3 illustrates concentrations of CFC-11 in the oceans, based on observations (top row), a baseline model simulation (middle row), and an improved version of the same model (bottom row). Compared to the baseline, the improved model simulation has lower CFC-11 concentrations in the deep Southern and South Atlantic Oceans, and agrees better with observed CFC-11 concentrations.

For further information on aspects of this program, contact any of the researchers.

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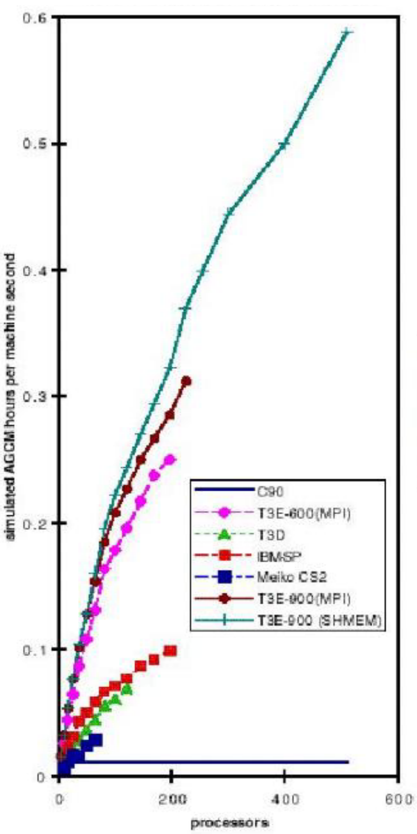

Figure 2. Multiprocessor execution speeds

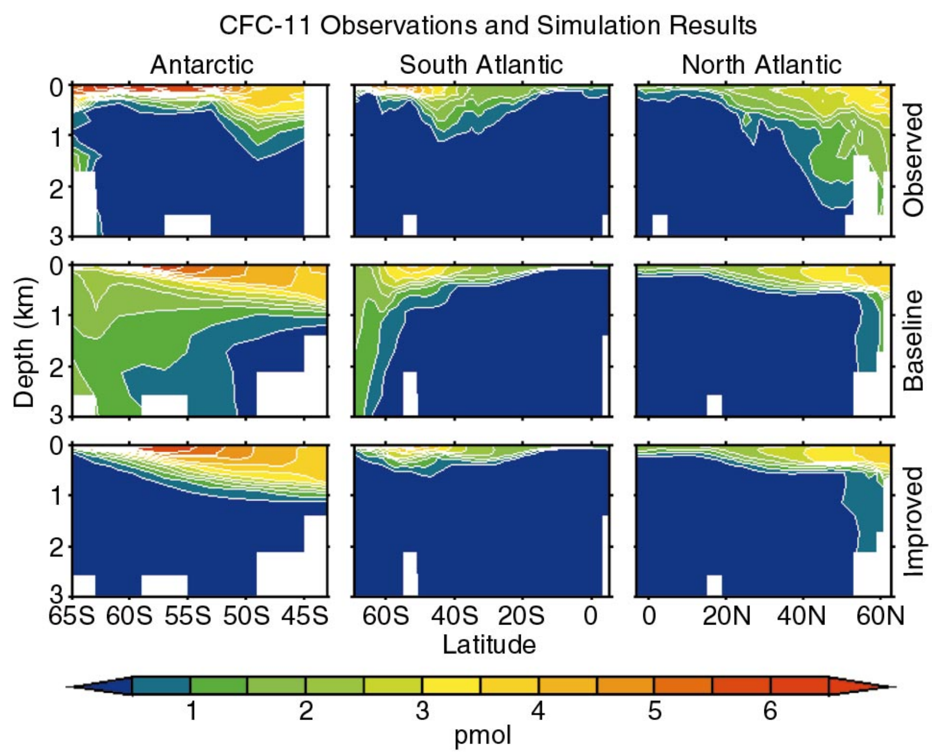

Figure 3. Column inventory of anthropogenic carbon dioxide, as computed by our coupled ocean circulation/biogeochemistry model.

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